fizjoterapia polska
nr 2/2014 (14)

Analiza goniometryczna wybranej klasy ruchu stawu kolanowego

Analysis goniometric of selected classes of traffic knee

Jędrzej Płocki[1(A,B,C,D,E,F)], Joanna Banaś[1(A,B,C,D,E,F)], Dominik Pikuła[1(A,C,D,E,F)], Andrzej Kotela[2,3(A,D,F)], Ireneusz Kotela[2,4(A,D,F)]

[1]Specjalistyczny Szpital im. Świętej Rodziny w Rudnej Małej. Oddział Rehabilitacji, Ruda Mała, Polska
[2]Centralny Szpital Kliniczny MSW w Warszawie, Polska
[3]Warszawski Uniwersytet Medyczny, I Wydział Lekarski, Katedra i Klinika Ortopedii i Traumatologii Narządu Ruchu, Warszawa, Polska
[4]Uniwersyte Jana Kochanowskiego w Kielcach, Polska

Streszczenie:
Wstęp.
Prawidłowy zakres ruchomości jest ważnym czynnikiem sprawności. Jego pomiar stanowi podstawę oceny stanu układu kostno-stawowego. Badanie zmian zakresów ruchu w funkcji czasu za pomocą elektrogoniometru dostarcza cennych i znaczących klinicznie danych. Celem pracy była próba określenia zmian dynamiki i zakresu ruchu w stawie kolanowym populacji osób zdrowych podczas wykonywania ruchu wejścia na stopień kończyną dolną dominującą.
Materiał i Metody.
Grupę badaną stanowiło 75 studentów Wydziału Medycznego Uniwersytetu Rzeszowskiego w wieku 18-26 lat. Badanie przeprowadzono przy pomocy urządzenia Noraxon 1400 L i kompatybilnego z nim dwuosiowego elektrogoniometru. Wstępnej obróbki dokonano w MS Excel. Analizę statystyczną przeprowadzono w programie Statistica 10,0 PL.
Wyniki.
Ustalono wartość normatywną dla maksymalnego kąta zgięcia stawu kolanowego podczas wejścia na stopień – 85,12˚ z przedziałem ufności 80,27-88,25˚.
Wnioski.
Istnieje potrzeba przeprowadzenia badań na większej, reprezentatywnej grupie w celu określenia normy dla maksymalnego kąta zgięcia stawu kolanowego podczas wejścia na stopień w badanej grupie wiekowej.

Słowa kluczowe:
Elektrogoniometr, wartość normatywna, staw kolanowy

Abstract
Introduction.
Normal range of motion of joint is an important factor of physical fitness. It's measurement makes up the basis of evaluation of the skeletal joint system. Analysing the changes in ranges of motion in the function of the time with the use of electrogoniometer provides valuable and meaningful data. The aim of the study was an attempt to determine the dynamics of change and the range of motion of the knee healthy population during going up the step of the dominant limb.
Material and Methods.
75 students of the Department of Medical University of Rzeszow, aged 18-26 were examined. The research was carried out with the use of Noraxon 1400 L system as well as compatible biaxial electrogoniometer. The preliminary process was performed in MS Excel. The statistical analysis was carried out in the Statistica 10.0 program.
Results.
Established normative value for the maximum angle of knee bends during going up the step – 85,12˚ with confidence interval 80,27-88,25˚.
Conclusions.
There is a need for research on a larger, representative sample in order to determine the standards for the maximum angle of knee flexion during the entry level in the studied age group.

Key words:
Electrogoniometer, normative value, knee joint

Introduction

Ambulation is a basic motor function in humans. It requires cooperation of the neuromuscular and skeletal system, controlled by the nervous system and requiring possibly the lowest energy expenditure. Normal ambulation pattern may be disturbed by numerous causes such as pain, reduced muscle strength, abnormal range of motion (reduced or expanded) or differences in the lengths of the lower limbs; therefore, accurate and precise analysis of gait is very important for the assessment of disturbances in human locomotion [1, 2].

One of the methods allowing to determine the range of motion in joints is electrogoniometry. Compared to conventional goniometer which requires static measurement conditions, electrogoniometer facilitates the examination of the dynamics of the joint motion. The examination is characterized by high repeatability and accuracy, thus providing important clinical information. The recorded data describe the functional capability of subjects, changes of angle joints as the function of time and the precise kinematics of motion. A properly conducted measurement of the range of motion is a basis for clinical examination and thus for correct rehabilitation management [3, 4].

Electrogoniometric measurements are versatile in application. They may be carried out in many areas, e.g. in medicine, sports, rehabilitation, ergonomics or robotics [5]. They facilitate accurate determination of joint angles as well as the dynamics of the changes in these angles. These issues constitute a part of rehabilitation engineering which is involved in the design, development and production of technologies to help solve problems encountered by dysfunctional patients [6].

An electrogoniometer facilitates precise recording of the dynamics of motion during functional activities, e.g. daily life activities. Examinations may be carried out in laboratory conditions as well as upon clinical examination [7]. They are precise and accurate as the electrogoniometer determines the rotation axis by itself and the range of motion is measured with the accuracy of 1.2o. The measurement is not disturbed by adverse environmental factors such as noise or temperature [4]. Electrogoniometers are characterized by small size and weight, ease of application at particular body segments as well as by not interfering with the subject's movements. Thanks to these properties, electrogoniometers are worldwide-proven and valued instruments [4, 5, 8].

The objective of the study was to attempt to determine the changes in the dynamics and the range of motion of the knee in a population of healthy individuals while carrying out the motion of climbing up a step using one's dominant limb, as well as to establish any variability ranges (confidence intervals, means, standard deviations) for highly consistent distributions. The procedure allowed the obtained results to be classified as normative values.

Material and methods

The study material consisted of 75 individuals randomly selected form the population of physiotherapy students at the Faculty of Medicine of the University of Rzeszów, including 40 females (46.7%) and 35 males (53.3%) aged 18-26 years, mean age of 21.8 ±1.74. The inclusion criterion consisted in completion of a questionnaire survey.

The study involved the use of a proprietary anonymous questionnaire, an electrogoniometer and descriptive statistical methods.

The questionnaire included the data on the age, body weight, BMI, dominant lower limb, history of injuries within lower limbs and cases of immobilization of lower limbs within the last 6 months.

Measurements of the range of motion were carried out using a Noraxon 1400L biaxial electrogoniometer with electrical sensor signal recording kit and MyoResearch XP Master Edition software (Fig. 1). The tool consists of two sensors connected by a flexible spring that compensates for the joint motion and relocation of the tool over the skin surface. This allows convenient measurements being carried out even on uneven body surfaces [5].

Fig.1 Electrogoniometer and MyoSystem 1400L

The electrogoniometer was mounted directly to subjects' bodies using Velcro straps and adhesive bandages placed in appropriate locations. The position of the electrogoniometer was determined according to the method by Rowe et al. [4] on the lateral side of the knee, perpendicular to the articular space, so that the center of the spring surrounding the shaft was located at the articular space level. Plastic blocks were fixed with Velcro straps to eliminate any movements between the device and the soft tissue.

Each subject had their studied limb appropriately exposed so that the motion of the knee would not be constrained. The subjects were also asked to take off their shoes and expose their feet. Following the fixation of the measurement tools, subjects were to stand in a neutral position in front of a black start line marked on the substrate so that their toes touched the line. Next, at the investigator's signal, subjects performed the motion of climbing up a step using their dominant limb and then bringing the other limb together with the dominant limb. Each subject was instructed on the motion to be performed and one trial motion was performed prior to the proper measurement. The motion was repeated three times so as to enable comparisons of the same types of values (Fig. 2).

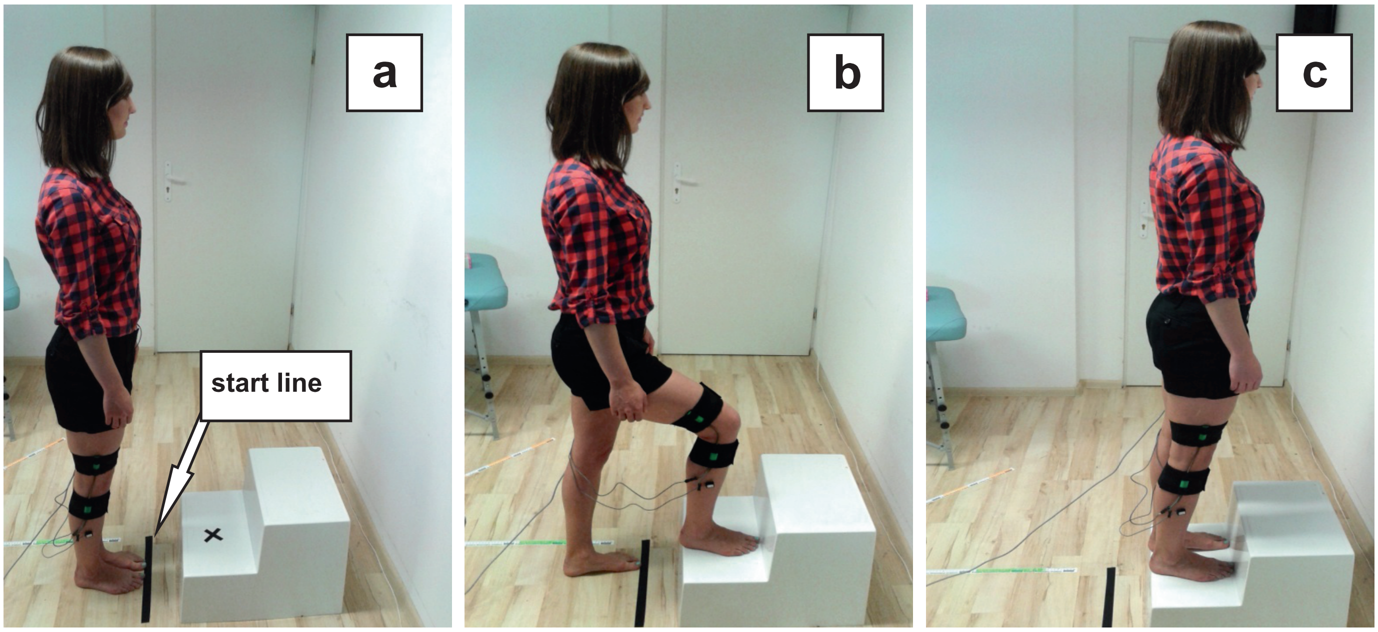

Fig 2. The person examined: a – before performing the task; b – during the task; c – after examination (Picture own)

The obtained mean values and standard deviations were entered into an MS Excel spreadsheet. The spreadsheet data were then subjected to statistical analysis using the Statistica 10.0 PL software. Means, standard deviations, inclinations, minimum and maximum angle values and medians were determined for each trial. Non-parametric Mann-Whitney U-test was used in the analysis of correlations between the distribution of tested variables and subjects' gender.

Results

The right leg was the dominant lower limb in 71 subjects; the left leg was dominant in the remaining 4 subjects. A total of 59 subjects (78.6%) in the study population declared no history of any injuries within the lower limbs. Eleven subjects (14.7%) had experienced injuries within the right lower limb, 3 subjects (4%) had experienced injuries within the left lower limb, while 2 subjects (2.7%) had experienced injuries within both the right and the left lower limb. In the period of the last 6 months, immobilization was applied in 1 subject while the remaining 74 subjects were not subject to immobilization in that period.
Following the analysis of outliers falling beyond the confidence limits, outlying records were eliminated from the study population. After this procedure, the study population consisted of 55 subjects, including 22 males and 33 females.
The study results showed that the mean flexion angle in electrogoniometric measurement was 21.9 ±4.57° in the first trial and 19.96 ±4,59° and 20.09 ±4.62° in the second and third trial,

respectively. In the first trial, the minimum flexion angle was 12° while the maximum flexion angle was 34.7°. In the second and third trials, the minimum values were similar and amounted to 10.1° and 10.4°, respectively. The maximum flexion angles measured in the second and the third trial were 31.3° and 35.7°, respectively. The analysis of distributions and descriptive statistics warrants the conclusion that the studied distributions did not comply with all conditions of normal distribution.

The mean maximum flexion angle in electrogoniometric measurement was 85.12°±11.57°, 83.72°±12.05°, and 83.21°±10.88° in the first, the second and the third trial, respectively. Minimum knee flexion angles in the first, the second and the third trial were 54.5°, 53°, and 56.6°, respectively. The respective maximum values were 113°, 109°, and 106°. Angle distributions in all trials were characterized by significant concentration and nearly full symmetry. The comparison of the mean values with medians and the occurrence of multiple maxima suggested significant deviations from normal distribution. Therefore, non-parametric tests were used in further analyses.

Non-parametric Mann-Whitney U-test was used in the analysis of correlations between the distribution of tested variables and subjects' gender. To this end, a zero hypothesis H[0] and an alternative hypothesis H[A] were formulated.

H[0] – the distribution is gender-independent.

H[A] – the distribution is gender-dependent.

Table 1. Mann–Whitney U test as regards: sex

Variable	Rank-sum (w)	Rank-sum (m)	U	Z	p	Z (correct.)	p	N import. (w)	N import. (m)
GN-1-sr	941.000	599.0000	346.0000	0.283473	0.776814	0.283514	0.776783	33	22
GN-1-A	992.500	547.0000	294.5000	1.168254	0.242705	1.168380	0.242654	33	22
GN-1-sr	982.500	557.0000	304.5000	0.996452	0.319031	0.996686	0.318918	33	22
GN-2-A	1007.000	533.0000	280.0000	1.417367	0.156377	1.417469	0.156347	33	22
GN-1-sr	915.5000	624.5000	354.5000	-0.137442	0.890682	-0.137484	0.890648	33	22
GN-1-A	997.5000	542.5000	289.5000	1.254155	0.209787	1.254291	0.209737	33	22

Selected results are important from p<0.05

GN-1/2/3-A – maksymalny kąt zgięcia stawu kolanowego w pomiarze 1/2/3; / maximum knee flexion angle in the measurement 1/2/3

For all distributions of the examined parameters, p values were higher from the statistical significance level (p=0.05), and therefore the zero hypothesis could not be rejected.

In relation to the p values and the fact that all the studied parameter distributions were independent of subjects' gender, further considerations were made without subjects' gender being taken into account. A more precise elucidation of correlations between distributions of study variables and subjects' gender are beyond the scope of this study.

In order to enable tabulated comparisons of the same type of measurable, the types of variables measured in 3 sequential trials was taken into account.

Wilcoxon matched pairs signed rank test was used to examine the variability of distributions of the study parameters in sequential trials by comparing trial 1 to trial 2 and trial 1 to trial 3.

H[0] – distributions in trial pairs 1-2 and 1-3 are not different.

H[A] – distributions in trial pairs 1-2 and 1-3 are different.

Table 2. The Wilcoxon test for mean values goniometric measurements

Variable	N important	T	Z	p
GN-1-sr & GN-2-sr	55	362.5000	3.414258	0.000640
GN-2-sr & GN-3-sr	55	452.0000	2.664378	0.007713

Selected results are important from p<0.05
GN-1/2/3-sr - average angle of knee flexion in the measurement 1/2/3

Table 3. The Wilcoxon test for goniometric measurement standard deviations

Variable	N important	T	Z	p
GN-1-A & GN-2-A	55	587.5000	1.529085	0.126244
GN-2-A & GN-3-A	54	517.5000	1.937299	0.052710

Selected results are important from p<0.05
GN-1/2/3-A – maximum knee flexion angle in the measurement 1/2/3

Distributions of mean values in trial pairs 1-2 and 1-3 were different since the p value was lower than the statistical significance level. Therefore, the zero hypothesis was rejected and the alternative hypothesis was accepted. For the distribution of standard deviation values in trial pairs 1-2 and 1-3, the p value was higher than the statistical significance level (p=0.05), which means that the study hypothesis cannot be rejected.

Wilcoxon test results for the maximum knee flexion angle values suggest a high stability of distribution in the study population. Taking into consideration the confidence interval and the results of the statistical test, one may conclude that the obtained GN-A value along with its corresponding confidence interval constitutes the normative value for that parameter.

One may therefore assume that the maximum knee flexion angle upon walking up a step in the age group of 18-26 years is:

85,12° (80,27-88,25°)

Discussion

The presented study methodology is a versatile analytical tool for the studies of human motion. It is worth mentioning that it may replace numerous tests and functional scales used to date by physicians and physical therapists while providing precise and reliable numerical data. The use of electrogoniometry in the population of healthy individuals provides valuable information on changes in joint angle values as the function of time, allowing to monitor the dynamics of motion during particular activities [3, 4]. The range of the changes in angle values affects the smoothness of motion. If the values are not constant, accelerations and

strains may develop within joints leading to the development of pathologies and injuries [9].
The results presented in this study allowed to generate a set of data regarding the changes of the range of knee flexion angles while walking up a step using one's dominant lower limb – an activity that may be related to everyday activity of climbing up stairs.
The available databases (Medline, Science Direct, PBL, PubMed, Health Source – Academic Edition) lacked studies of similar nature, i.e. conducted in populations of healthy adults. Evaluations of the ranges of motions of individuals with evident pathological changes within the lower limbs are obviously incomparable with the results of this study.
The assessment of the dynamics of the changes in joint angles in the course of specific functional activities requires appropriate equipment. According to Rowe et al. [4], flexible goniometers may provide such possibility as being inexpensive, relatively simple to operate and convenient during the conduct of the experiments. According to the researchers, the method may be used in routine functional tests in clinical trials. In order to demonstrate the usefulness of electrogoniometers, they were compared to the Vicon system consisting of 5 cameras and markers being placed on the subjects. The studies were conducted in 5 individuals (2 males and 3 females aged 30-52 years), whose task was to walk a 10-m section of the floor 5 times. Differences in mean flexion angle values as measured by both methods after walking the entire distance were lower than 1° while falling in the range of 1.5 ±2.8° for a single walk cycle. Thus, examinations using electrogoniometers turned out to be accurate, precise, and requiring no expensive equipment. Bronner et al. [10] demonstrated that examinations using flexible goniometers were reliable and valid for the measurements of extreme motions of lower limbs. Also other authors [11], having performed a systematic review of literature on the reliability and accuracy of the tools for the measurement of the range of motion of the knee joint concluded that examinations using electrogoniometers were the most reliable, as they were characterized by low measurement errors. Linden et al. [12] demonstrated high repeatability of measurements made using flexible goniometers while walking on flat substrates, inclined ramps, as well as climbing up and walking down the stairs.
Electrogoniometry is a method allowing to perform accurate and repeatable measurements during the functional activity of the knee, thus allowing for unambiguous determination of the success or the failure of therapeutic management [13].
The reported method for the measurement of the ranges of motion was also applied in the assessments of occupational body postures [14]. It allowed to determine the professional risks as well as to establish programs for prevention and treatment of e.g. musculoskeletal disorders [15, 16].
Walking the stairs is one of the very important activities of everyday life. For the purposes of assessment of pathologies or treatment results, it is important to know the range of knee flexion angles required to achieve proper ambulation pattern. This is possible only in case when a reference standard for this range of

motion is available. Determination of the standard requires very long and tedious, multicenter clinical trials. Obviously, the results obtained in this study do not meet all the criteria of a standard, and therefore they are referred to as normative values.
No standards for the knee flexion angles in the studied age group were found in the literature. Therefore, the conducted electrogoniometric measurements as well as the results obtained in these measurements may be used as grounds for determination of standards that allow to assess the degree and extent of pathologies within the lower limbs. To this end, the population of subjects within the particular age group should be significantly increased. The presented study methodology is worth using in further analyses of healthy individuals.

Conclusions

1. The normative value of the maximum knee flexion angle upon walking up a stair was determined as 85.12° with the confidence interval of 80.27-88.25°.
2. It is worthwhile to perform the analysis of "raw" data so as to determine the ranges of the changes in the knee flexion angle occurring in time.
3. Due to the small study population, the measurements are of preliminary nature and do not allow to determine a standard for the range of knee motion for the particular age groups. This means that these results should be verified in a larger group that would be representative for the entire population.

adres do korespondencji / corresponding author

Jędrzej Płocki
Czarna Górna 63/1, 38-710 Czarna,
e-mail: jplocki@gazeta.pl,
tel.: +48 781 529 464.

Piśmiennictwo/ References

1. Drużbicki M., Szymczyk D., Snela S., Dudek J., Chuchla M.: Obiektywne, ilościowe metody analizy chodu w praktyce klinicznej, Przegląd Medyczny Uniwersytetu Rzeszowskiego, 2009, 4, 356-362.
2. Gross J., Fetto J., Rosen E.: Badanie układu mięśniowo-szkieletowego, PZWL, Warszawa, 2011.
3. Shiratsu A., Coury J.: Reliability and accuracy of different sensors of a flexible electrogoniometer, Clin Biomech, 2003, 18, 682-684.
4. Rowe J., Myles M., Hillmann J., Halewood E.: Validation of flexible electrogoniometry as a measure of joint kinematics, Psyhioterapy, 2001, 87, 479-488.
5. www.noraxon.com
6. Będziński R., Kędzior K., Kiwerski J., Morecki A., Skalski K., Wall A., Wit A.: Tom 5. Biomechanika i inżynieria rehabilitacyjna, Akademicka Oficyna Wydawnicza Exit, Warszawa, 2004.
7. Urwin S., Kader D., Caplan N., Gibson A., Stewart S.: Validation of an electrogoniometry system as a measure of knee kinematics during activities of daily living, Journal of Musculoskeletal Research, 2013, 16, 1.
8. Tesio L., Monzani M., Gatti R., Franchignoni F.: Flexible electrogoniometers: kinesiological advantages with respect to potentiometric goniometers, Clin. Biomech, 1995, 10, 5, 275-277.
9. Będziński R.: Biomechanika inżynierska, Oficyna Wyd. Politechniki Wrocławskiej, Wrocław, 1997.
10. Bronner S., Agraharasamakulam S., Ojofeitimi S.: Reliability and validity of electrogoniometry measurement of lower extremity movement, Journal of Medical Engineering & Technology, 2010, 34, 3, 232-242.
11. Piriyaprasarth P., Morris M. E.: Psychometric properties of measurement tools for quantifying knee joint position and movement: a systematic review, The Knee, 2007, 14, 1, 2-8.
12. M. L. van der Linden, Rowe P. J., Nutton R.W.: Between-day repeatability of knee kinematics during functional tasks recorded using flexible electrogoniometry, Gait & Posture, 2008, 28, 2, 292–296.
13. Cleffken B., Breukelen G., Brink P., Mameren H., Damink S. O.: Digital goniometric measurement of knee joint motion. Evaluation of usefulness for research settings and clinical practice, The Knee, 2007, 14, 385-389.
14. Vieira E. R., Kumar S.: Working Postures: A Literature Review, Journal of Occupational Rehabilitation, 2004, 14, 2, 143-159.
15. Foltran F., Silva L., Sato T., Coury H.: Wrist electrogoniometry: are current mathematical correction procedures effective in reducing crosstalk in functional assessment?, Brazilian Journal of Physical Therapy, 2013, 17, 1, 32-40.
16. Yen T., Radwin R.: Comparison between using spectral analysis of electrogoniometer data and observational analysis to quantify repetitive motion and ergonomic changes in cyclical industrial work, Ergonomics, 2000, 43, 1, 106-132.